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VEHICLE DRIVE CONTROL FOR 4X4 MODE

Background of the Invention

1. Field of the Invention

The present invention relates to an electronic control system and method for controlling a torque output of a vehicle drive in a manner that is less sensitive to accelerator pedal position when the vehicle drive is in a 4X4 mode of operation.

2. Description of Related Art

Motor vehicle internal combustion engines may be controlled using a torque control scheme where actual engine torque is controlled to a desired engine torque through an input adjusting device, such as with the electronic throttle, ignition timing, air-fuel ratio, or various other devices.

A torque-based electronic throttle (ETC) driver demand control system has been developed for use with all-wheel drive vehicles with manual and automatic transmissions. The ETC driver demand control system has employed a calibration table to provide a desired output torque in response to inputs to the table. For manual transmission applications, the inputs to the calibration table have been the engine speed and accelerator pedal position. For automatic transmission applications, the inputs to the calibration table have been the transmission output shaft speed and accelerator pedal position.

In manual transmission applications, the calibration table having inputs of engine speed and accelerator pedal position has been used to provide a wheel torque output in response to driver demand, regardless of whether the motor vehicle is operating in one of the normal drive gear modes or in a 4X4 low mode. In automatic transmission applications, the calibration table having inputs of transmission output shaft speed and accelerator pedal position has been used to provide a transmission output shaft torque in response

to driver demand, regardless of whether the motor vehicle is operating in one of the normal drive gear modes or in a 4X4 low mode. Use of a calibration table in such a manner produces torque outputs that are distorted during operation of the vehicle drive in different modes as a result of the need to account for the 4X4 low mode of operation and also the normal drive gear modes of operation. For example, the wheel torque (manual transmission) or output shaft torque (automatic transmission) can be overly sensitive to accelerator pedal position when the vehicle drive is operated in the 4X4 low mode.

An object of the present invention is to provide an electronic control system and method for controlling a vehicle drive in a manner to overcome this problem of distortion and over-sensitivity of torque outputs to the position of the accelerator pedal when the vehicle drive is operated in a 4X4 mode.

Summary of the Invention

The present invention provides pursuant to an illustrative embodiment an electronic control system and method using a unique calibration table indicating a relationship of torque output as a function of accelerator pedal position and a speed parameter, such as engine or transmission output shaft speed, to provide torque output values specifically applicable to a 4X4 mode operation of the vehicle drive, such as for example only a 4X4 low mode of operation. For example, the present invention provides an electronic control system and method using a unique calibration table stored in control memory to control torque output values appropriate for the 4X4 low mode of operation of the vehicle drive unit. When the vehicle is operated in one of the other modes of operation, the control system uses a different stored calibration table indicating a different relationship of torque output as a function of the accelerator pedal position and the speed parameter appropriate to that mode of operation.

In an automatic transmission application with the 4X4 low mode operable (active), a unique stored "4X4 low" calibration table is provided that renders the output shaft torque values less sensitive to the accelerator pedal position when the automatic

transmission selector is placed in a drive "D" or overdrive "OD" mode.

In a manual transmission application with the 4X4 low mode operable (active), a unique stored "4X4 low" calibration table is provided that renders the engine torque output values less sensitive to the accelerator pedal position when the manual transmission selector is placed in gears other than park or neutral.

The present invention is advantageous to provide improved vehicle control and driver feel when the vehicle drive is in a 4X4 mode of operation so that the output torque is less sensitive to accelerator pedal position. The above objects and advantages of the present invention will become more readily apparent from the following description taken with the following drawings.

Brief Description of the Drawings

Figure 1 is a block diagram of a vehicle illustrating various components related to the present invention.

Figures 2A, 2B, 2C, 2D are stored calibration tables that indicate a relationship of output torque as a function of accelerator pedal position (accelerator foot pedal angle) and a speed parameter (output shaft rpm or engine rpm) and that can be used in practice of an illustrative embodiment of the invention. Figure 2E is a calibration table indicating a relationship of accelerator pedal position and desired engine speed over idle speed.

Detailed Description of the Preferred Embodiment

Referring to Figure 1, an internal combustion engine 10 of a motor vehicle is shown coupled to a vehicle drive 14 that includes a conventional manual or automatic transmission 14a and a conventional transfer case 14b. The engine 10 can be coupled to the transmission 14a in conventional manner and has a torque output and a rpm output applied to transmission 14a. Transmission 14a is coupled to a first set of drive wheels 20 and can be coupled to transfer case 14b and in turn to a second set of drive wheels 22 when demanded by the vehicle driver to provide on all wheel (4-wheel) drive operation. The transmission 14a can comprise a manually actuated gear set of a

manual transmission, a combined gear set and torque converter of an automatic transmission, a continuously variable transmission, or any other drive unit known to those skilled in the art.

A manual transmission 14a is operable by the vehicle driver using a conventional transmission shifter 15 shown for convenience disposed on steering column 17 but more typically disposed on a vehicle floor console (not shown), or elsewhere in the vehicle, to manually shift among forward drive gears, 1, 2, 3, 4, etc. and reverse. An automatic transmission 14a is operable by the vehicle driver using a conventional transmission shifter 15 that can be placed, for example, in a park ("P"), reverse ("R"), neutral ("N"), drive ("D"), or low ("L") selector position in conventional manner. Additional transmission selections such as drive gear 3, 2, 1, etc. also can be provided on the transmission shifter selector as is known.

The transfer case 14b is drivingly coupled to the second set of drive wheels 22 when demanded by the vehicle driver to provide on all wheel (4-wheel) drive. The transfer case 14b is electrically controlled by selector switch 19, for example only, located on the dashboard 21 of the vehicle to permit the driver to select a particular 4-wheel drive mode of operation. For example only, the driver can select among all-wheel 4X4 mode ("A4WD"), 4X4 high mode ("4H"), and 4X4 low mode ("4L"). The "A4WD" mode is an optional mode of operation selectable by the vehicle driver and is controlled by electronic controller EC to automatically provide a 4X4 mode of operation (e.g. the "4H" mode of operation) when a certain amount of slippage is detected at the wheels 20 and/or 22. Otherwise, the electronic controller EC will command the "2H" mode of operation described below. Wheel slippage is detected by comparing speed signals from first wheel speed sensor 30 for the first set of drive wheels 20 and/or from second wheel speed sensor 32 for the second set of drive wheels 22. The wheel speed sensors 30, 32 are used in conjunction with the "A4WD" mode and are not necessary if the "A4WD" mode is not provided as an available mode of operation of the drive unit.

The "4L" mode of operation is a driver-selected and controlled mode of all wheel drive operation typically operable at relatively low vehicle speeds than the "4H" mode. For example, the

"4L" mode of operation typically is used for operation of the vehicle in deep mud, deep snow, rough rocky terrain, or pulling heavy loads such as for example only pulling out tree stumps. The "4H" mode of operation is a driver-selected and controlled mode of all wheel drive operation typically operable at relatively higher vehicle speeds than those of the "4L" mode. Such all-wheel drive settings are used on the Lincoln Navigator sport utility vehicle manufactured by the Ford Motor Company for example. The "2H" selector setting shown provides a two wheel drive mode of operation where transmission 14a is coupled only to wheels 20.

An accelerator pedal 40 is shown communicating with the driver's foot 42. Accelerator pedal position is measured by one or more pedal position sensors 44 (one shown for convenience) and sent to electronic controller EC. The pedal position sensor 44 can comprise a conventional brush type of position sensor, or other suitable position sensor.

Electronic controller EC receives various signals from sensors coupled to the engine 10, transmission 14a, transfer case 14b, and the vehicle. These sensors include an output shaft speed sensor 31 to sense the rotational speed (rpm) of the output shaft OS of the transmission 14a and a 4X4 mode switch sensor 33 to sense the position of switch 19. The sensors also can include first wheel speed sensor 30 for the first set of drive wheels 20 and second wheel speed sensor 32 for the second set of drive wheels 22 if the "A4WD" mode is provided as an available mode of operation of the drive unit. The wheel speed sensors 30, 32 can comprise conventional Hall effect rotation sensors. An engine sensor 54 is provided to sense rpm of the engine 10 and can comprise a conventional Hall effect rpm sensor. Other sensors 52 (shown schematically) can be provided to sense engine coolant temperature, air charge temperature, transmission oil temperature and other variables.

Electronic controller EC is a conventional microcomputer including a microprocessor unit 102, input/output ports 104, electronic read only (ROM) memory chip 106, which is an electronically programmable memory in this particular example, random access memory (RAM) 108, and conventional data bus line.

Controller EC is shown controlling the engine 10, the transmission 14a, and transfer case 14b, although the invention is

not so limited since the engine, the transmission, and the transfer case each can be controlled by an individual electronic controller or the engine and transmission can be controlled by an electronic controller while the transfer case is controlled by its own electronic controller. In a particular embodiment, the engine 10 is electrically controlled by an electronic throttle control (ETC) system 110 interfaced with electronic controller EC. In such an electronic throttle control system for a vehicle with an automatic transmission, the engine 10, transmission 14a, and transfer case 14b are controlled in response to the accelerator pedal position and the transmission output shaft speed, with modifications for barometric pressure (BP) and engine coolant temperature (ECT) and air charge temperature (ACT), to produce a desired (driver demanded) output shaft torque value. The ETC system 110 can be of the type described in copending application Serial No. 09/532 685 filed January 21, 2000, the teachings of which are incorporated herein by reference. As discussed in the Background Information above, the output shaft torque of such ETC system can be overly sensitive to accelerator pedal position when the vehicle drive is operated in the 4X4 low mode as a result of use of a particular calibration table that does not distinguish between the 4X4 low mode of operation versus other modes of operation of the drive unit.

In accordance with an illustrative embodiment of the invention, electronic controller EC embodies in controller memory one or more special calibration tables applicable specifically to the 4X4 low mode of operation ("4L" mode) of the vehicle drive 14, while one or more different, other calibration tables are stored in controller memory and are applicable to other modes of operation of the vehicle drive unit.

For purposes of illustration and not limitation, Driver Demand Tables are set forth below illustrating five (5) stored calibration tables pursuant to an illustrative embodiment the invention for use in connection with manual transmission and automatic transmission embodiments of the invention. The calibration tables 1-4 indicate a relationship of output torque (output shaft torque or engine torque) as a function of accelerator pedal position (pedal foot angle degrees) and a speed parameter (output shaft RPM or engine RPM. Figures 2A through 2E illustrate the five stored tables

listed in the Driver Demand Tables.

DRIVER DEMAND TABLES

1) Table of output shaft torque-F(pedal position, output shaft speed) for non-4L mode
2) Table of engine torque-F(pedal position, engine speed) for non-4L mode
3) Table of output shaft torque-F(pedal position, output shaft speed) for 4L mode active
4) Table of engine torque-F(pedal position, engine speed) for 4L mode active
5) Function that outputs engine speed-F(pedal position) for Park and Neutral

APPLICATION COMBINATIONS:

Trans	4L Active	PRNDL	Table	Speed In	Torque Out
Manual	No	All but P,N	2	engine	
Manual	Yes	All but P,N	4	engine	
Manual	Yes	P,N	5	N/A	N/A
Manual	No	P,N	5	N/A	N/A
Auto	No	D,OD	1	OS	
Auto	No	All gears but D,OD,P and N	2	engine	
Auto	Yes	D,OD	3	OS	
Auto	Yes	All gears but D,OD,P and N	4	engine	
Auto	Yes	P,N	5	N/A	N/A
Auto	No	P,N	5	N/A	N/A

where Trans is transmission type (manual or automatic), engine is engine speed, OS is output shaft speed and N/A is not applicable.

As is apparent from the Driver Demand Tables, for a manual transmission, the stored calibration tables 2 and 4 are used by the controller EC to determine an engine (crankshaft) torque output value from an accelerator pedal position input and an engine speed input. For example, when the "4L" mode is inactive, stored calibration table 2 is used in all transmission settings, except "P" and "N", by controller EC to provide an engine torque output in dependence on the accelerator pedal position and engine speed (rpm). When the "4L" mode is active, a different stored calibration table 4 is used in all

transmission settings, except "P" and "N", to provide an engine (crankshaft) torque output in dependence on the pedal position and engine speed (rpm). Calibration tables 2 and 4 are selected to provide for engine braking when the "4L" mode is active or inactive. Calibration table 4 differs from calibration table 2 to provide a change in engine torque versus position of the accelerator pedal that is more gradual than that provided by table 2; e.g. see Figures 2B and 2D. Use of table 4 when the "4L' mode is active renders the engine torque output less sensitive to accelerator pedal position to provide improved vehicle control and driver feel when the vehicle drive 14 is in the "4L" mode of operation, for example, over rough rocky terrain.

When the "4L" mode is active or inactive and the transmission selector is placed in the "P" or "N" mode, stored calibration table 5 shown in Figure 2E is used by controller EC to provide a desired engine speed over idle speed in dependence on accelerator pedal position. Table 5 is provided to permit the vehicle driver to rev the engine in "P" or "N" to a desired engine speed over idle speed without the controller EC generating engine or output shaft torque values.

As is apparent from the Driver Demand Tables, for an automatic transmission, the stored calibration tables 1 and 3 are used by the controller EC to determine an output shaft torque value from accelerator pedal position input and the output shaft speed input. The output shaft torque is related by the transmission gear ratio and torque converter ratio as a multiplier to engine torque. The output shaft speed is sensed by rpm sensor 31. Vehicle speed is determined from the output shaft speed. The stored calibration tables 2 and 4 are used to determine an output shaft torque value from accelerator pedal position input and output shaft speed (rpm).

For example, when the "4L" mode is inactive with an automatic transmission setting of "D" or "OD" (over-drive if present), stored table 1 is used by controller EC to provide an output shaft torque in dependence on the accelerator pedal position and the output shaft speed (rpm). When the "4L" mode is inactive with the transmission setting in any setting except "D", "OD", "P", and "N", stored table 2 is used to provide an engine output torque in dependence on the accelerator pedal position and the engine speed

(rpm).

When the "4L" mode is active with a transmission setting of "D" or "OD", stored calibration table 3 is used by controller EC to provide an output shaft torque in dependence on the accelerator pedal position and the output shaft speed (rpm). When the "4L" mode is active with the transmission setting in any setting except "D", "OD", "P", and "N", stored table 4 is used by controller EC to provide an engine torque output in dependence on the accelerator pedal position and engine speed (rpm). Tables 2 and 4 are selected to provide for engine braking when the "4L" mode is active or inactive and the transmission selector is in any gear except "D", "OD", "P", and "N". Calibration table 3 differs from calibration table 1 in a manner to provide a change in engine torque versus position of the accelerator pedal that is more gradual than that provided by table 1; e.g. see Figures 2A and 2C. Use of table 3 when the "4L" mode is active renders the engine torque output less sensitive to accelerator pedal position to provide improved vehicle control and driver feel when the vehicle drive 14 is in the "4L" mode of operation, for example, over rough terrain.

When the "4L" mode is active or inactive and the transmission selector is placed in "P" or "N", stored calibration table 5 is used by controller EC to allow the driver to rev the engine in "P" or "N" without generating engine or output shaft torque values.

Although the illustrative embodiments of the invention have been described hereabove with respect to use of one or more special calibration tables for the "4L" mode of operation, those skilled in the art will appreciate that the invention is not so limited and can be practiced using different calibration tables applicable specifically to the "4H" mode of operation as well, whether the "4H" mode is selected by the vehicle driver using switch 19 or by the electronic controller EC in the "A4WD" mode of operation.

Although certain embodiments of the invention have been described herein, the invention is not limited to these embodiments as changes and modifications can be made thereto within the scope of the invention as set forth in the appended claims.